

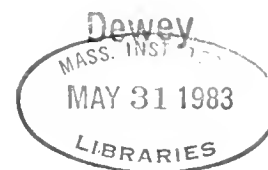
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ADMINISTRATIVE SCIENCE AND SYSTEM DYNAMICS:

FILLING THE GAP IN MANAGEMENT EDUCATION

by

John D. W. Morecroft

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## ABSTRACT

Current management education lacks a component that adequately examines the decisionmaking structure of a business enterprise and the relationship between structure and corporate performance. This paper proposes a new combination of administrative science and system dynamics to fill the gap. Three educational tasks are outlined. The first task is to make students aware of the sharp distinction between the monolithic, highly integrated decision processes used in making personal choices and the loosely coupled, decentralized decision processes that an organization uses to make business choices. The second task is to teach students how to chart the decentralized structure of business decisionmaking--its anatomy and physiology--and relate the structure to factoring, goal formation, tradition, routines and corporate culture. The final task is to teach students how to diagnose business problems in terms of deficiencies in the decisionmaking structure, using the simulation modeling methods of system dynamics. A two-semester course sequence in business administration and modeling is outlined to give a practical illustration of the content of new curriculum materials. The outline draws on the author's experience in teaching and research at the Sloan School of Management, M.I.T.



## UNDERSTANDING BUSINESS ADMINISTRATION

A key educational role of business schools is to inject young minds with understanding and enthusiasm for business administration. The task is not unlike one of training a physician. Students must become familiar with the anatomy and physiology of organizations. They must develop the appropriate vocabulary for describing the parts of an enterprise, understand how the parts are linked together, and finally appreciate how the parts interact to influence the success of the business.

The educational process that leads up to business school is largely devoid of content that deals with the nature and structure of organizations. Curricula that address human enterprise and human affairs tend to personify organizations and governments, making their actions seem like those of rational individuals. [1] But organizations do not function like rational individuals.

It is in the process of making and executing decisions that an organization differs radically from an individual. The actions of a business firm are the result of many loosely coordinated decisions--not the result of a monolithic, highly integrated thought process. Coordination is achieved (though not always successfully) through sensible partitioning of responsibilities, negotiation and discussion, and a shared value system impressed by the culture, tradition, incentives and routines of the enterprise. [2]

The thesis of this paper is that standard MBA curricula fail to familiarize students sufficiently with basic principles of organization, administration, and enterprise design. [3] The gap can be filled by a new combination of administrative science and system dynamics that exposes students to the administrative structure of real organizations and illustrates, through simulation modeling, the difficulties of coordinating the many decisions and actions of a live enterprise.

The paper is divided into three sections. The first section discusses the gap left in management education by the traditional management science and pragmatic schools. The second section proposes a new combination of administrative science and system dynamics that fills the educational gap. The third section outlines a two-semester course sequence in business administration and modeling as a practical illustration of the content of new curriculum materials. The outline draws on the author's experiences in teaching and research at the Sloan School of Management, M.I.T.

#### THE GAP LEFT BY MANAGEMENT SCIENCE AND THE PRAGMATIC SCHOOL

An essay criticizing a field that is not the focus of one's professional activity risks appearing superficial to experts in the field. Here, the intention is to identify gaps left in management education by the traditional management science and pragmatic schools, and not to gainsay the contribution of either school to the advance of management practice. The perspective is that of someone who has received a representative sample of the educational offerings of management science and the pragmatic school

and who has an established professional research base in the areas of system dynamics and administrative science. [4]

### Management Science

From the student's point of view, management science emphasizes improving the quality and effectiveness of individual management decision processes: demand forecasting, marketing, production planning and control, sales force sizing, capacity and facilities planning, warehouse and distributor location, machine-shop scheduling, and so forth. In each case, the student examines, as if through a magnifying glass, some small part of the overall decisionmaking structure of the enterprise--often with the purpose of devising an algorithm that will optimize performance.

In setting up an optimizing algorithm, a student learns many valuable things. For example, in using linear programming to derive an aggregate production plan, he learns about the cost structure of manufacturing and the relative importance of labor, inventory, and overtime costs. He becomes aware of the capacity constraints that limit the range of feasible production plans. He develops an appreciation for the trade-offs between overtime and inventory carrying costs. [5]

But in bringing the magnifying glass down on production planning, the student loses sight of the way production interacts with the rest of the manufacturing and delivery system and with the business enterprise as a whole. A broader perspective is important. A real manufacturing system is

composed of many decision functions for ordering, inventory control, production planning, capacity planning, and labor hiring that link the activities of distributors, warehouses, manufacturers, and suppliers. Constraints on capacity and labor assumed in the cost minimization for production planning themselves depend on policies for ordering capacity and hiring labor elsewhere in the system. By placing these policies outside the boundary of the optimization problem, important aspects of enterprise design may be inadvertently overlooked. For example, a policy for hiring labor that deliberately maintains a "labor reserve" can relieve capacity constraints on production and therefore change the conditions surrounding "optimal" planning. Executives and managers need to understand the joint effect of the many manufacturing policy levers under their command if they are to provide effective and intelligent leadership for their firm.

The management science approach can be criticized on another level. It is an approach to problem solving in business that perpetuates the emphasis, so prominent in the normal educational process, on excellence and cleverness of the individual's solution. By contrast, the effective manager or executive needs an attitude to problem solving that generates excellence and cleverness of the organization. The organizational and individual solutions need not be the same. For instance, a solution to the problem of reducing manufacturing costs might be to use inventories to decouple the many decision functions of a multistage production and distribution system. [6] Viewed through the magnifying glass of the



management scientist, these inventories may appear wasteful. From the perspective of the businessman and administrative scientist, the inventories may be essential for creating an integrated yet simple-to-manage manufacturing system. By decoupling stages of production, people can be held accountable for performance against targets for production, shipping, and inventory. But by focusing on isolated decision functions, the management science approach may propose solutions that actually undermine the conditions for successful cooperation and for the exercise of authority, so essential to the smooth functioning of an enterprise.

#### The Pragmatic School

The pragmatic school holds that experience is the key to management education. Taken to its logical extreme, this view implies that formal business education per se is of no value and that the best way to educate a manager is to apprentice him in a real organization. [7]

The less extreme pragmatic school holds that some combination of experience and illustrative case histories is the appropriate way to educate a manager. Practically all business schools function in part according to the pragmatic school. For example, at the M.I.T. Sloan School of Management most students have two or more years of experience before entering the masters program. They all take at least one intensive policy and strategy course based on the case method. The Harvard Business School is still further along the spectrum of pragmatism, attracting experienced students and devoting a large portion of the curriculum to the case method.

The shortcoming of the pragmatic school is its lack of general principles for analyzing business problems. For example, a Harvard Business School case study entitled "The Saturday Evening Post" (1972) advances as many as ten different "theories" to account for the failure of the Curtis Publishing Company and the death of its most famous publication, The Saturday Evening Post. At one point, editorial policy is held responsible for the decline. Elsewhere, the corporate strategy to build a "fully integrated magazine publishing company" is brought into question. The case implies that a company which grows its own trees, makes its own paper, and distributes its own magazines is at a disadvantage to more focused competitors due to the "size and complexity of corporate management." Another part of the text suggests that a decrease in the Post's attractiveness to advertisers led to a decline in advertising revenues and subsequent financial loss. The case concludes with the suggestion that the Post fell victim to political fights and personality conflicts among executives and members of the board.

All these theories are plausible. But one is confronted with a variety of symptoms and no framework for discerning the most likely underlying causes. Closer investigation of the text reveals a looseness in premise and conclusion of the theories that often makes diagnosis of the problem ambiguous. For example, the argument that vertical integration increases the size and complexity of corporate management (with the implication that integration is a weak strategy) completely overlooks the organizational measures for factoring responsibilities and therefore

simplifying the management of a vertically integrated firm. (Peters and Waterman, 1982, pp. 306-317)

Advocates of the case approach will doubtless counter by arguing that the managerial lessons in the case lie not in the text alone, but in its interpretation. There is much truth in the argument--but the value of the case method is then only as good as the interpreter and his personal "framework" for business policy analysis. Moreover, there is no guarantee of consistency among alternative interpretations. The case method alone can cover a vast territory of business policy issues and develop students' confidence in articulating opinion. But by itself it is not a discipline for the diagnosis of business problems. It is more of an art.

#### ADMINISTRATIVE SCIENCE AND SYSTEM DYNAMICS--FILLING THE GAP

The thesis of this paper is that administrative science and system dynamics together can fill the educational gap left by management science and the pragmatic school. Moreover, the appropriate combination of these disciplines can create a stimulating and challenging set of curriculum materials for use in business schools that may go some way to realizing the vision of management education expressed by Forrester (1968, pp. 414-415):

In response to the systems challenge we should expect to see a core being developed through the entire management curriculum. This core will be a new ensemble of subjects that deal with the mathematics of systems, the dynamic principles of systems, the conversion of experience and descriptive knowledge to a precise structured form, policy design through simulation experiments, coordination of model systems that builds descriptively and intuitively beyond a foundation of policy studies in the form of dynamic models.

Administrative science is a field which, broadly defined, could include contributions from political scientists, behavioral economists, cognitive psychologists, sociologists, and students of industrial organization. The paper presents an important branch of administrative science most closely associated with the writing of Herbert Simon and the Carnegie school. This branch takes as its focus the decisionmaking process in organizations and is, in Allison's (1971, p. 71) words,

an attempt to understand the basic features of organizational structure and function as they derive from the characteristics of human problem solving and rational choice.

The writings of the Carnegie school lay bare the anatomy and physiology of the business organization. They reveal how decisions are actually made, not how they should be made. In Simon's words (1976, p. 220):

The anatomy of the organization is to be found in the distribution and allocation of decisionmaking functions. The physiology of the organization is to be found in the processes whereby the organization influences the decisions of each of its members--supplying these decisions with their premises.

#### Bounded Rationality

The starting point for understanding organizations is the principle of bounded rationality. One cannot overemphasize the educational importance of this concept, which is paid only lip service in management science and is absent or at best implicit but unrecognized in all other academic disciplines. Yet it is the sine qua non of organization.

The principle of bounded rationality (Simon, 1957, p. 198) asserts that the capacity of the human mind for formulating and solving problems is much smaller than necessary to guarantee objectively rational behavior in even moderately difficult choice problems. The statement is rather innocuous and abstract, but the implications are far-reaching. Problems of choice in business organizations are very complex. As a result it is impossible for any individual to be in command of an organization in the sense that he or she makes and executes all the essential decisions.

Students should study the procedures of organization--factored decisionmaking, goals and rewards, routines, culture and tradition--that leverage the bounded rationality of individuals into a more comprehensive organizational rationality.

#### Anatomy of the Organization--Factored Decisionmaking

Organizations simplify their complex choice problems by factoring them into small pieces. Factored decisionmaking is an inescapable empirical feature of all organizations (Allison, 1971, p. 80) (Simon, 1976, pp. 221-222). There are immediate structural implications of such an arrangement. Information, and therefore knowledge, about the state of the enterprise is distributed among various executives and managers. Each decisionmaker receives only part of the information flow. Each sees only a fraction of the total picture--an amount sufficiently small to allow him to cope with his own local choice problem in a timely fashion. Organizations are clearly a long way from being monolithic thinkers; they are systems of weakly-coupled distributed thinkers.

Students should be exposed to the idea of factored decisionmaking by studying alternative forms of organizational design such as functional versus divisional, or matrix versus hierarchical, as in Hax and Majluf (1983). They should be made aware of factored decisionmaking in their personal lives and in the various organizations in which they participate (the university, the home, extracurricular organizations). Finally, they should be given some vivid illustrations of the potential difficulties of factored decisionmaking, perhaps by playing "games of bounded rationality" --classroom games in which factored decisionmaking and bounded rationality are implicit in the design of the game (an example is provided later in the paper).

#### Physiology of the Organization--Influences on the Decision Process

The organization has many ways to influence the choices and actions of its members, and so coordinate its factored decisionmaking. Any manager or administrator must have a good grasp of these methods of influence--they provide the key to organizational design.

Below are listed some of the methods of influence as described in the writings of the Carnegie school, system dynamics, behavioral economics, and cognitive psychology. More explicit references to the literature will be provided within each subheading. The list is by no means exhaustive; it simply reflects the limits of the author's experience and research.

### Goal Formation and Incentives

Goals and incentives influence the choices of an individual. They focus his attention on a small part of the enterprise and make him responsible and accountable for its success. They determine what information is viewed as important and what irrelevant at different parts of the organization. Students should study the process of goal formation in organizations. They should be exposed to the powerful influence that goals and incentives can have on behavior. For example, an instructor might deliberately manipulate course evaluation criteria and later analyze the effects on student behavior. More conventional analysis of case material might illustrate the effects of goals and incentives in a business setting.

### Authority, Culture, and Style

Authority, culture, and style are intangibles, yet they have a most pronounced impact on decisionmaking (Simon, 1976, pp. 125-134) and in many cases differentiate the successful company from the mediocre or failing enterprise. Case studies and simulation models can illustrate how authority and culture permeate thinking at decision nodes, influencing the selection and interpretation of information and thereby affecting corporate performance.

For example, in an interesting case modeled by Forrester (1967) the president of a company with a fast-growing new product line insisted on maintaining strict personal control over the approval of all capital expenditures. As a result, there was a bias in the decision function for

capital equipment ordering. Considerable demand pressure (in the form of high order backlogs) had to accumulate to justify capacity expansion. The simulation model that incorporated this facet of executive style and authority showed that such a bias could, in the context of the rest of the organization, cause growth to stagnate in a potentially limitless market.

### Routine and Memory

Organizations are great storehouses of specialized decision process and routine (Nelson and Winter, 1982, pp. 96-136) (Cyert and March, 1963, pp. 101-113). Its experienced members carry around in their heads a repertoire of standard responses to situations that recur in day-to-day business operations. Routines are an important influence on decisionmaking. They simplify choice but introduce momentum into organizational behavior. An organization that encounters rapid change in its environment, say, its market, may find its repertoire of standard responses inappropriate to the new situation.

Management education should expose students to the existence and implications of organizational routine. Appeals to personal experience can doubtless bring the topic alive. Behavioral simulation models which incorporate routine, such as Forrester (1967), Roberts (1974) and Mass (1978), can drive the point home.

### Basic Cognitive Processes

When the organizational influences on the decision process have been exhausted there remain the limitations of basic cognitive processes. [9]



People take time to collect and transmit information. They take still more time to absorb information, process it, and arrive at a judgment. There are limits on how much information they can manipulate and how much they can retain in memory. Cognitive processes can introduce delay, distortion, and bias into information channels in the organization and are therefore an important part of the physiology of organization.

Students of management should be made aware of cognitive limitations, through reading, classroom demonstrations, and behavioral simulation models.

#### Summary

A full treatment of the physiology of the organization using appropriate literature, classroom demonstrations and simulation models could form a stimulating and rewarding core of management education. With a basic knowledge of organizational anatomy and physiology, a management student is better equipped to understand the business enterprise he or she enters, to diagnose its strengths and weaknesses, and ultimately to contribute intelligently to its design and evolution.

#### System Dynamics--An Appropriate Calculus

One drawback of administrative science has been its inability to relate organizational processes to the success of an enterprise. Precisely how does the behavior of an organization--its financial performance, its market penetration, its growth or decline--relate to its underlying

decisionmaking structure? System dynamics is a discipline which provides the appropriate calculus for demonstrating how assumptions about business decisionmaking produce observed behavior.

Before describing the role of system dynamics in management curricula, a few words about the discipline itself are in order. To many management educators, system dynamics is simply a tool, synonymous with the DYNAMO simulation language it uses. This perception is inaccurate. The discipline is much more appropriately viewed as a branch of administrative science that recognizes implicitly cognitive and behavioral limitations on organizational decisionmaking, and has evolved a powerful and flexible calculus for describing business decisions and analyzing their interaction. Figure 1 shows how system dynamics fits into and extends the broad field of administrative science.

First, the subject contains a wealth of observations into the nature of human enterprise and organization and so has much in common with administrative science. The following excerpts from Chapter 10, "Policies and Decisions," in Forrester (1961) illustrate the empirical emphasis of system dynamics:

Actual, effective decision functions in a company or in an economy go much further than the formal policy that is set down in executive memoranda and in laws. The "effective policy" is the framework for reaching decisions and is established by the environment, the sources of information that are in fact available, the success measures and rewards that affect people at each decision point, the priority order of food and shelter and luxuries... and the prejudices and habits impressed by past experience (p. 101).

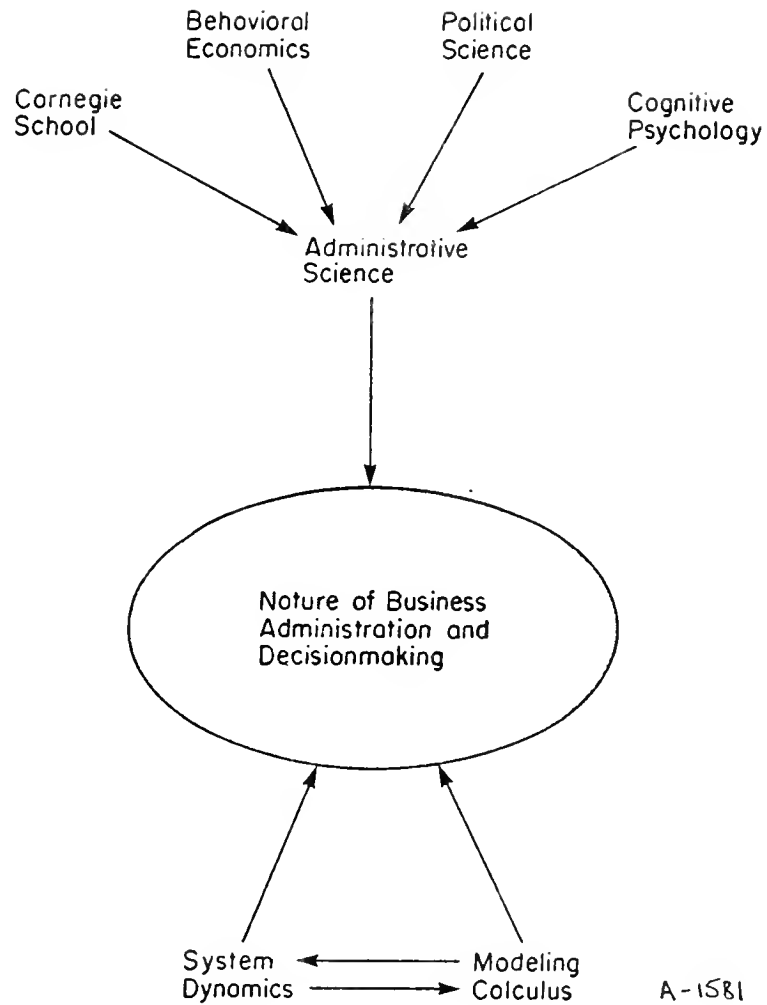


Figure 1. System Dynamics--A Behavioral Philosophy and a Modeling Calculus

...The human decision maker is usually using a great deal less than the total amount of information available to him...what he does with these few sources of information is apt to be rather stereotyped (p. 100).

The current management press such as Business Week, the Wall Street Journal, and Forbes, is filled with the rationale for management decisions. Much of the printed material is devoted to a discussion of the pressures of the current state of affairs and the effects these will have on decision makers (p. 98).

The subject also contains a refined modeling calculus that is well attuned to describing and analyzing decisionmaking in business and social systems. The term "calculus" here implies more than a modeling tool. As Little (1970) has pointed out, a calculus for management is not only a set of numerical procedures for describing and diagnosing business problems, but also a set of procedures that are communicable, robust, easy to control, adaptive, and capable of incorporating judgmental information. In short, the modeling calculus is a method of computation and analysis that is closely matched to the administrative problems to which it is applied.

#### TWO-SEMESTER SEQUENCE IN BUSINESS ADMINISTRATION AND MODELING

This section describes a sequence of two courses intended to provide students with a "feel" for organizational decisionmaking. The courses show how an organization is structured, how structure determines performance and generates problems, and how simulation modeling is used to diagnose and remedy business problems. The material draws heavily on the author's experience in teaching introductory and intermediate courses in system dynamics in the masters program of the Sloan School of Management at M.I.T.

The existing courses, however, do not contain the strong "behavioral/administrative" component of the proposed sequence.

### Business Administration and Modeling I

Business Administration and Modeling I is conceived as an introductory course to be taken by all entering students in a professional business degree program. The course differs substantially from standard business modeling courses. A large proportion of the course, one-third to one-half, is devoted to covering basic "principles of administration" and learning how to chart the anatomy and physiology of the organization. The modeling language and its syntax are introduced later in the course to illustrate the formulation of specific features of organizational decisionmaking such as factoring, routine, goal formation, incentives, authority, tradition and culture.

### Principles of Administration

The course begins by discussing the notion of bounded rationality and then developing its implications for organization structure and process. The first step is to make students vividly aware of the universal existence of bounded rationality in problem solving and decisionmaking. Class discussion of various board games may bring the topic to life. For example, to contrast the meaning of objective rationality and bounded rationality a comparison of the complexity of thought required for playing tic-tac-toe (noughts and crosses) versus chess would be appropriate.

The next step is to address how organizations deal with complex choice problems--driving home the point that they do not in general seek objectively rational solutions. There should be discussion and illustration of the organizational procedures that "transform intractable decision problems into tractable ones." Simon (1979, p. 501) provides a useful summary of some of the topics to be covered.

One procedure is to divide up the decision making task among many specialists, coordinating their work by means of a structure of communications and authority relations.

Students can be exposed to the many examples of factored decisionmaking in organizations/social groups with which they are familiar. They can also learn to chart the decision nodes and information flows that result from factored decisionmaking, thereby gaining some early exposure to the diagramming tools of the modeling calculus to be introduced formally later in the course.

Another (procedure) is to replace abstract, global goals with tangible subgoals whose achievement can be observed and measured.

The discussion of organizational goal formation should draw on material such as (Cyert and March, 1963, pp. 26-43) and (Forrester, 1975, pp. 167-174). Examples of the formation of manufacturing goals for inventory and shipping and marketing goals for market share, revenue and sales can illustrate the general idea and prepare the way for later formal modeling.

Another (procedure) is to look for satisfactory choices instead of optimal ones.

Again, examples of common organizational practice for establishing "acceptable" targets for, say, sales volume, inventory turnover, financial performance, etc. would illustrate the point.

Similarly, organizational routine and rules of thumb should be discussed to uncover the habits present in the "thinking patterns" of organizations. Finally, the basic cognitive limitations of individuals--the limits on their ability to collect and process information--should be discussed as the ultimate limitation on rational decisionmaking. Again, the key to holding the interest and attention of students is to bring these topics to life with vivid illustrations from everyday experience of working and thinking in human organizations.

#### System Difficulties Arising from Bounded Rationality

The structure of an enterprise evolves to leverage the limited rationality of individuals into a more comprehensive organizational rationality. But the structure can be flawed. Students should be exposed at an early stage (before they have built a model) to the systemic difficulties arising from bounded rationality. The best way to provide this exposure is to use classroom "games of bounded rationality."

One excellent example of such a game is the production and distribution hand-simulation game (Lyneis, 1980, pp. 465-470). Students are divided into teams of four. Individuals play the role of retailer, wholesaler, distributor or manufacturer in a production and distribution system. The wholesaler, for example, accepts orders from the retailer, makes shipments, controls inventory, and decides how much to order from the distributor. The game contains many of the standard organizational procedures for simplifying choice: factored decisionmaking, local goals,

and rules of thumb (for ordering and inventory control). The game provides a vivid illustration of the difficulties of coordinating the many policies for ordering and inventory control. The system always produces wild fluctuations in order rates and inventory levels, despite the best attempts of the players to manage their own part of the system prudently, in accordance with local goals.

Other games of bounded rationality could be devised for different decisionmaking situations. For example, an elaborated version of the Parker Brothers stock market game Pit (1980) might make some interesting points about speculative movements in stock prices resulting from the bounded rationality of the traders.

#### Introducing the Administrative Calculus

With some appreciation of the structure of organizations, and the nature of organizational decisionmaking, students are now ready to learn the administrative calculus of system dynamics.

The first requirement (before being exposed to any computer modeling language or mathematical notation) is to learn the diagramming tools for charting the organization structure. The most appropriate tools are the system flow diagram described in Forrester (1961, pp. 81-85) and Lyneis (1980, pp. 35-74) or the more compact but less precise policy structure diagram described in Morecroft (1982,1). The application of these tools can be illustrated with examples in marketing, manufacturing, and distribution (Morecroft, 1982,2).



### Rationality and Structure in Production and Distribution

An effective way to introduce the modeling language DYNAMO is to use it to formulate equations for a real organizational problem. For example, one might model the structure causing fluctuations in production, employment, and inventory levels in manufacturing firms. This "reference mode" serves as a focus for the selection of decisionmaking processes (Forrester, 1961, pp. 208-215). A policy structure diagram is developed that portrays common policies for production planning, forecasting, inventory control, labor planning, and hiring. The diagram is then converted into DYNAMO equations (Pugh, 1976), thereby introducing students to the syntax of the programming language. In developing the formulations, attention is drawn to the organizational procedures implicit in the policy structure: factoring of decisionmaking to production control and labor management, local goals for inventory and planned labor, and rules of thumb for forecasting, inventory adjustment, and labor adjustment.

Once the model is formulated, simulation analysis is used to diagnose the causes of the empirically observed fluctuations in production and employment. Students can be given exercises to explore how the inventory control and forecasting functions work in isolation--when there are no lags in adjusting production to planned production. Similarly they can explore how the labor hiring function adjusts to an exogenous request for additional labor. In both these partial model tests, the adjustment of the decision functions is plausible and intuitively obvious. However, when the functions are linked, so that production depends on the size of the labor

force, and planned labor is influenced by adequacy of inventory, the system tends to fluctuate. The simulation analysis shows that production and employment fluctuations arise naturally by linking (locally) rational policies for inventory control and labor hiring.

The staged development of a simple manufacturing model achieves several ends in advancing administrative and modeling skills. It shows how to relate the boundary of a model to a specific business problem. It shows how common organizational procedures can be portrayed graphically and in equations. It introduces the simulation language DYNAMO as a natural part of the modeling calculus. It introduces simulation analysis to explore the rationality of isolated parts and combinations of the decisionmaking structure.

#### Rationality and Structure in Capital Investment and Marketing

An excellent follow-up to introductory production and distribution models is Forrester's (1967) "Market Growth" model. The model contains capacity planning and marketing policies for a growth company. The policies can cause sales of the company's product to stagnate or decline in a potentially limitless market. The model is compact, but intricate. It contains formulations that show how executive style and authority influence the premises of decisionmaking for capital equipment ordering, causing insufficient capacity expansion in the system as a whole. It also contains an interesting rule of thumb for establishing the marketing budget. [10]

The formulation of the model is subtle, and so is its behavior. Analysis of the market growth model provides an excellent opportunity to devise partial model tests to build understanding of complex system behavior. Partial tests can explore the behavior of individual feedback loops in the system's decisionmaking structure. Students can learn how to relate concise pictures of feedback structure (causal-loop diagrams) to particular modes of simulated behavior such as growth, fluctuation, and stagnation.

#### Rationality and Structure Elsewhere in the Organization

The remainder of the Business Administration and Modeling I course comprises examples of policy structure drawn from elsewhere in the organization. The method of development in each case would be similar to the method outlined above. Modeling is motivated and focused on an issue or problem. The policy structure is sketched. The sketch is translated into DYNAMO equations, and simulation analysis is used to elucidate the behavioral and structural causes of observed problems.

There is a rich variety of structures available in the system dynamics literature and, therefore, a number of ways of completing the course content. For example, Roberts (1964) has used system dynamics modeling to study cost overruns in the management of large R&D projects. The managerial insights from this work can be captured in compact educational models that portray policies for monitoring and reporting progress on a project and for hiring skilled engineers. (Richardson and Pugh 1981, pp.

190-213) Hall (1976) describes a system dynamics model used to diagnose the collapse of the Saturday Evening Post--a problem referred to earlier in the paper. Morecroft (1983,1) develops a model that shows how productivity in a sales organization can be cut in half by policies for setting sales objectives and sales effort.

### Business Administration and Modeling II

Business Administration and Modeling II advances the students' understanding of organization and business policy by (1) having them work on a semester-long project addressing a live business problem, (2) using traditional case studies and models of cases to debate business policy, (3) covering advanced issues in model formulation and testing, and (4) developing the communication and debating skills needed to bring about organizational change.

Students are divided into teams of two or three to work on live business problems with sponsoring firms. Four or five different projects provide a rich empirical base for classroom discussion. For example, in recent project courses at M.I.T., students have addressed problems of human resource management for a professional services firm (Achi and Mott, 1982); investment strategy in the electronic image processing industry (Graham and Kreutzer, 1983); marketing strategy for a leading company in the data communications market (Morecroft, 1983,2); and finished inventory investment strategy for a leading filtration equipment manufacturer (Maffione, 1982). Live projects are supplemented with traditional case studies amenable to modeling such as the Harvard Business School Case on the demise

of the Saturday Evening Post (1972) and the University of Virginia Case on the marketing strategy of the British Motorcycle Industry (1980).

Live projects must be carefully managed to yield results that are useful to the student teams and the sponsoring organization. Students should work on problems and issues of significance to a company, with managers who are committed to seeking workable solutions, and who attach importance to the project. [11] Experience at M.I.T. has shown that this working relationship is best forged in a formal sponsored research program (Morecroft, 1983,3). Sponsoring companies pay a fee for membership and designate a responsible liaison person. An experienced faculty member works closely with the student/firm "task force" in the selection of a problem. The course comprises three phases: problem definition and conceptualization, problem diagnosis and analysis, and the implementation of change. [12]

In the problem definition phase student teams familiarize themselves with the sponsoring organization or with the details of the written case. Students typically spend one or two full days early in the semester meeting with company managers to identify a relevant problem and to review the company's current plans and opinions for resolving the problem. Class sessions are divided equally between lectures (some by outside consultants) on the process of problem selection and model conceptualization, and presentations in which students describe their field experiences of abstracting a problem/issue from a (usually) messy and imprecise initial

management "concern." One project, for example, began from a vague management concern with "difficulties in manufacturing." Ultimately the project focused on the company's loss of (highly profitable) service parts market share and explored how the loss was related to policies for production planning, dealer ordering, and capacity allocation (Morecroft, 1983,4).

In the diagnosis and analysis phase, student teams formulate and test a system dynamics model relating the business problem/issue directly to organizational structure and process. Each team presents its model in class for appraisal. Student presentations are supplemented with lectures on model formulation and testing that emphasize nontechnical/intuitive methods of model development and interpretation. Lectures on model formulation stress the importance of developing equations that show the premises of decisionmaking explicitly: the goals toward which local decisions adjust, the incentives that direct actions to the achievement of goals, the organizational routines, and the influences from executive authority and corporate culture. Lectures on model testing focus on the use of partial model tests (tests of small pieces of the decisionmaking structure) to reveal the intended rationality of decisionmaking, and on the contrast of partial and whole model tests to diagnose problem or surprise behavior.

[13]

During the implementation of change phase, a blend of student presentations, case histories, and communication clinics is used to illustrate

the challenges of implementing policy change in an organization. Students present the policy recommendations from their project models and the sponsoring company's reactions. Case histories are presented (some by outside speakers) based on past research and consulting projects. Traditional case studies are used to round out the discussion and to illustrate the differences between model-based and intuitive business policy analysis. Communication clinics, conducted by experts in business communication, are used to teach students the basic oral and "visualizing" skills needed to make effective presentations that influence executive opinion and company policy.

#### CONCLUSION--PIECING TOGETHER THE MANAGEMENT EDUCATION PUZZLE

A new combination of administrative science and system dynamics has been proposed to fill a gap in management education. The crucial gap is in concepts and materials that treat administrative processes, decisionmaking structure, and the consequences of structure for the performance of the enterprise.

Figure 2 is the author's image of the completed management education puzzle including administrative science. Four interconnected boxes are shown. In the bottom left is management science encompassing operations management, marketing, finance, classical economics, management information systems MIS, and decision support systems DSS. In the bottom right is policy and strategy, drawing on the case method, business experience, industrial economics, and industrial organization. In the upper right is

behavioral and cognitive science drawing on cognitive psychology, sociology, and anthropology. In the upper left is administrative science encompassing the Carnegie school, system dynamics, and behavioral economics.

Administrative science adds an important focus on the organization to the management education puzzle. In management science the focus is on the decision function--the best way to design and support individual decisionmaking processes in an organization. In policy and strategy the focus is on descriptive reality of the enterprise. In behavioral and cognitive science the focus is on the psychological, motivational, and cognitive properties of individuals and groups. Administrative science and system dynamics contribute a unique focus on the interaction of many decision functions of many individuals.

Administrative science and system dynamics do more than fill a gap in management education. They establish a rich communication junction between the other management disciplines, offering students the benefits of a more integrated education, and researchers the advantages of cross-fertilization. In the figure this role as a communication junction is shown by interconnections between the boxes. Between administrative science and management science is a connection that promises to yield better understanding of the design of organizational decision processes--a first step in realizing the design principles of "enterprise engineering." Knowledge of hierarchical decisionmaking and decision support from management science



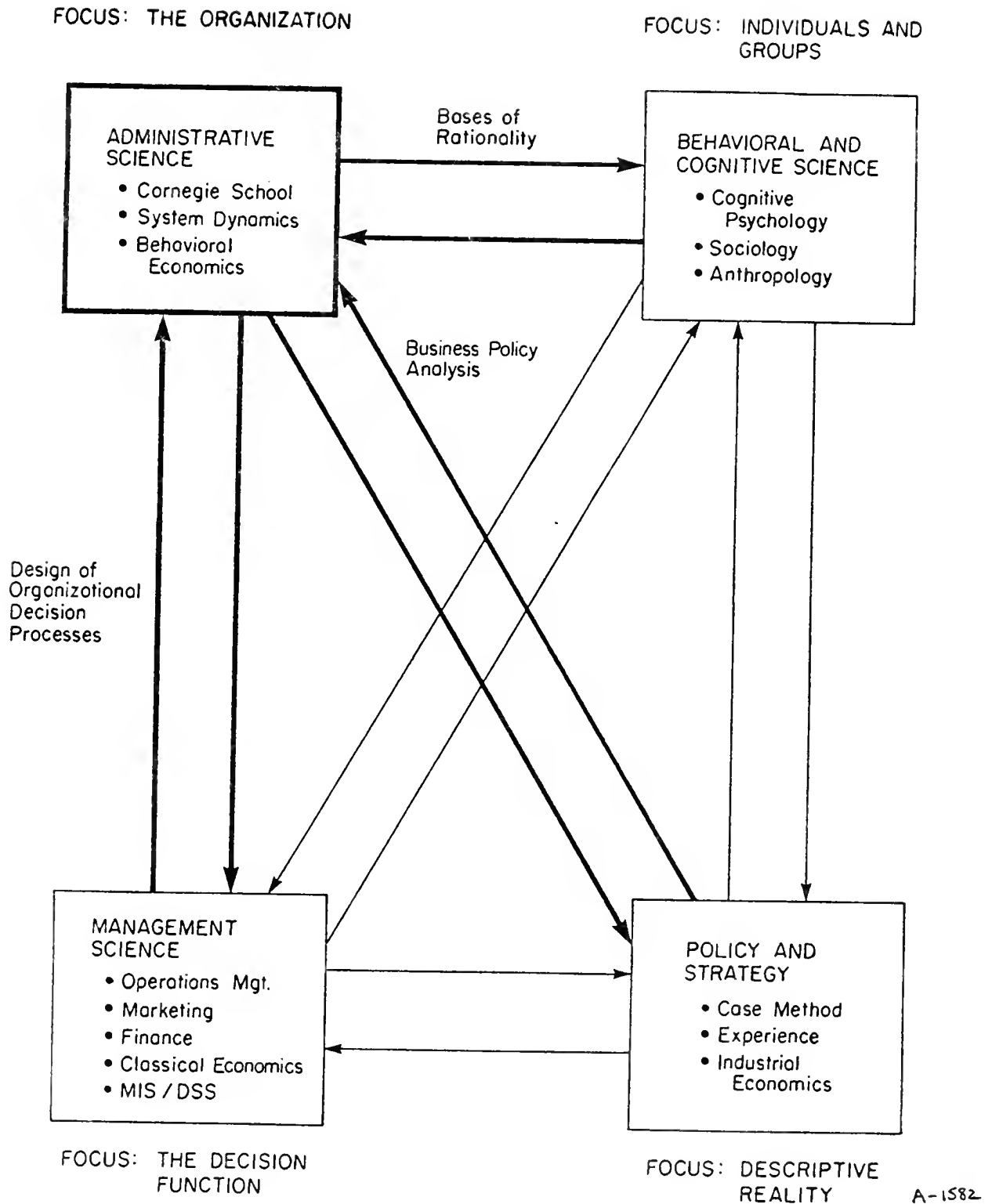


Figure 2. Piecing Together the Management Education Puzzle

can be blended with knowledge of organizational structure and behavior from administrative science to design better networks of rational decision-making. Between administrative science and policy and strategy is a connection that can improve business policy analysis and the understanding of administrative structure and process. This connection blends the descriptive/anecdotal database of policy and strategy with the organizing concepts of the Carnegie school and system dynamics. Finally, between administrative science and behavioral and cognitive science there is a connection that promises to yield better understanding of the bases of rationality in organizational decisionmaking.

The completed puzzle of management education presents an intellectually challenging and substantive base for the training of business leaders, and a broad agenda for future research and curriculum development.

## NOTES

- [1] Allison (1971) describes the personification of organizational actions as "the rational actor paradigm."

Most analysts and ordinary laymen attempt to understand happenings in foreign affairs as the more or less purposive acts of unified national governments. Laymen personify rational actors and speak of their aims and choices....Strategic analysts concentrate on the logic of action in the absence of an actor (pp. 4-5).

- [2] See Simon (1976), in particular Chapter 5, "The Psychology of Administrative Decisions," for an elaboration of this crucial point.
- [3] See Forrester (1961, Chapter 3) and Richmond (1983) for further discussions of the terms "enterprise design" and "enterprise engineering."
- [4] More specifically, knowledge of management science has come from the author's involvement in masters and doctoral programs in management at leading business schools in England and the United States, and three years' work experience in the operational research group of a leading European manufacturer. Knowledge of the so-called pragmatic school is derived partially from exposure to the case method, from work experience, from numerous business policy research projects conducted at M.I.T., and from administrative experience gained as an M.I.T. faculty member.
- [5] See, for example, Holt, Modigliani, Muth, and Simon (1960) and Bitran and Hax (1977).
- [6] Van Dierdonck and Miller (1980) talk about the trade-offs between inventory investment and manufacturing complexity. Morecroft (1983,4) provides an explicit example of inventory investment used to solve an organizational problem in manufacturing. Skinner (1974) addresses the issue of decoupling and manufacturing complexity in his concept of the "Focused Factory."
- [7] The author feels that resistance in the British educational system to management education is partly a function of this attitude, deeply ingrained in the minds of many established executives. Leaders in British industry are not pressing unanimously for formal management education, and the academic community, feeling vaguely uncomfortable with management as a legitimate discipline, is feeling no pressure to change its views.

- [8] For an informative treatment of organizational goal creation, see Allison (1971, p. 82), Cyert and March (1963, pp. 26-43), Forrester (1975, pp. 167-174), and Simon (1976, pp. 112-117).
- [9] For a thorough and readable account of cognitive limitations in human choice, see Hogarth (1980).
- [10] See Morecroft (1983,5) for an interpretation of the rationality of decision functions in the Market Growth Model.
- [11] For a valuable discussion of the process of establishing a successful corporate modeling project, see Roberts (1977).
- [12] For a description of the course outline now used at M.I.T., see Morecroft (1983,6).
- [13] For a discussion of premise description and partial model testing in system dynamics models, see Morecroft (1983,1). Also see Mass (1981) for an insightful discussion of diagnosing surprise model behavior.

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